thirteen feet one inch, the other twelve feet six inches, which may be taken as the average size of the circumference of the head of the full-grown male.

In the past three seasons I have seen thousands of them; and from constant careful observation while they were in life, and very often close about the ship—also when dead, examining many of their skulls after being taken on board and flenched, the only conclusion that can be come to is, that there is but one species of the Bottlenose Whale inhabiting the Northern seas. There are no flat-headed females. It is only the older males that have the flat perpendicular heads notched back towards the beak, with high crest and close frontal bones.

The accompanying sketches of male Whales (figs 1–5, p. 728), and photographs of their skulls (figs. 6–9, p. 729), will help to show how their heads flatten, and also the progressive manner in which the bones of the head enlarge and close up as they become older.

3. On the Classification of the *Comatulæ*. By P. Herbert Carpenter, M.A., Assistant Master at Eton College.

[Received November 23, 1882.]

In the last part of the Proceedings of this Society Prof. F. J. Bell [1] has proposed "a method of formulating the results attained to, as regards our knowledge of the specific characters of the members" of the family *Comatulidæ*.

That such a method is absolutely necessary for systematic work in a family which comprises so few genera but so many species, was made clear to me before I had been studying the group for many months; and I was therefore in no way surprised to hear that Prof. Bell had arrived at the same conclusion soon after his commencing the examination of the large collection of *Comatulæ* in the British Museum, together with the very remarkable series sent home by Dr. Coppinger, of H.M.S. 'Alert.' I am sorry, however, that Prof. Bell has so soon published his system of formulation; for I cannot but think that a little more experience of the remarkable variations in the group-characters would have caused him to modify it considerably.

I had intended to reserve any publication of the method of formulation which has gradually developed itself during my work on the 'Challenger,' 'Blake,' and other collections, until the appearance of the 'Challenger' Report. But the numerous errors contained in Prof. Bell's paper require an immediate correction, which would be out of place in the 'Challenger' volumes.

Prof. Bell's method is an ingenious one, especially where he

[1] "An Attempt to apply a Method of Formulation to the Species of the *Comatulidæ*; with the Description of a new Species," P. Z. S. 1882, part iii. pp. 530–536, Pl. XXXV.

applies it to denote the varying characters of the cirri; and I shall have much pleasure in employing it to this extent. His idea of distinguishing *Antedon* and *Actinometra* by *A* and *A'* respectively is also a good one; though I should myself prefer *A* and *a*, as being less liable to printers' errors.

He gives formulæ for 58 species, 12 of which are MS. names of his own; but of the remaining 46 formulæ, no less than 12 would lead a collector who depended upon them for identification of a specimen to form a false conception of the corresponding species. In the case of *Act. parvicirra* and *Act. novæ guineæ*, the error is but a slight one. But the formulæ given for *Act. bennetti*, *Act. peroni*, *Act. schlegeli* and other species denote a type of the genus which I have never met with, much less described; and were it not that I am now prepared for nearly any freak of nature among these animals, I should almost venture to call it a "Comatulid impossibility."

Eight of these twelve species (including the three above mentioned) have been described by myself in the 'Notes from the Leyden Museum,' vol. iii.; and as these Notes have a far less wide circulation than the Proceedings of the Zoological Society, it is necessary to prevent other workers from forming the wrong conceptions of these types which would result from the exclusive use of Prof. Bell's formulæ.

The errors are in the parts of the formulæ which denote the characters of the rays and their subdivisions, the remaining portions, which indicate the positions of the syzygies in the arm-bases and the characters of the cirri, requiring no alteration. As regards the former, Prof. Bell says:—

"If (1) we use the letters *R*, *D*, *P* for the radials, distichals, and palmars respectively, and insert them in the formula whensoever the respective axillary is a syzygy, we may (2) distinguish which of the first three brachials (one of which is, with but with very rare exceptions, a syzygy) is a syzygy by simply making use of the number 1, 2, or 3.... When a character frequently, though not always, obtains, the corresponding letter is put within brackets. ... When D or P appear in a formula it is clear the species must have more than 10 rays[1], because of the meaning of the words those letters represent; where, however, neither distichals nor palmars present a syzygial joint, it will be necessary to make use of the mathematical sign for the square root to mark the fact of its being a multiradiate species" (pp. 531–532).

[1] Prof. Bell has here confounded the ten primary arms with the rays proper, by the division of which these arms originate. This has led him into much confusion, as will be pointed out later. According to Müller, "Radien nenne ich die auf dem Knopf aufgesetzten Stämme der Arme.... Auf jedem der 5 *Kelchradien sitzen* 2 *Arme*, die entweder einfach bleiben oder sich noch einmal oder mehrmal wieder theilen." ("Ueber die Gattung *Comatula*, Lam., und ihre Arten," Abhandl. d. Berlin. Akad. 1849, p. 240.) The arms therefore were clearly distinguished from the rays by Müller; and it is a pity that Prof. Bell has confounded them, especially as in the genus *Promachocrinus* there actually are ten rays springing directly from the centrodorsal.

The following are cases in which Prof. Bell has wrongly applied his own method:—

1. *Antedon macronema.* According to Bell's formula $\left(3\,A\frac{bc}{c}\right)$ this species only differs from the ten-armed *Ant. rosacea* $\left(3\,A\frac{bc}{a}\right)$ in the cirri consisting of more than 40, instead of less than 20 joints. And yet Müller[1] says, "Ans den 5 Armstämmen von 3 Radialgliedern entwickeln sich meist 3 Arme, so dass sich ein Stamm zuerst in einen dicken und dünnen theilt, der dickere aber über dem zweiten Glied oder *brachiale axillare* sich wieder in 2 Arme theilt." The "*brachiale axillare*" is what we now call the "distichal axillary;" and as it does not "present a syzygial joint," Prof. Bell's formula should be $\sqrt{3\,A\frac{bc}{c}}$.

2. *Antedon palmata.* The same formula is given for this species $\left(3\,A\frac{b}{b}\right)$ as for *Ant. carinata*, which has ten undivided arms. In *Ant. palmata*[2], however, "Die 10 Primärarme bestehen aus 2 Gliedern, das zweite axillar. Nach der Theilung wieder 2 Glieder, das zweite axillar. Entweder bleibt es dabei oder die Arme theilen sich wieder." That is to say, there are two distichals and two palmars, and sometimes even a further division, none of the axillaries being syzygies. Hence the formula should be $\sqrt{3\,A\frac{b}{b}}$; but this is insufficient, as it gives no information about the presence of any axillaries beyond the distichal one.

Both the errors above noticed are due to the omission of the sign $\sqrt{\ }$, and are possibly due to the printer. But others are of a much more serious character and require to be treated in more detail.

3. *Act. alternans.* For $3A'RPP''\frac{o}{o}$ read $3\,A'DP'(P''')\frac{o}{o}$.

4. *Act. bennetti.* For $3\,A'RDP\frac{c}{b}$ read $3\,A'DPP'(P'')\frac{c}{b}$.

5. *Act. japonica.* For $\sqrt{3\,A'R\frac{c}{b}}$ read $3\,A'DP\frac{c}{b}$.

6. *Act. multiradiata.* For $2A'RDP\frac{b}{b}$ read $2A'DP(P')\frac{b}{b}$.

7. *Act. novæ-guineæ.* For $1(2)A'RDP\frac{b}{\times}$ read $1(2)A'RDPP'(P'')\frac{b}{\times}$.

8. *Act. parvicirra.* For $3\,A'DP\frac{(b)}{a}$ read $3\,A'D(P)\frac{(b)}{a}$.

9. *Act. peroni.* For $3A'RDP\frac{b}{b}$ read $3\,A'DP(P')\frac{b}{b}$.

10. *Act pulchella.* For $(1.2)3A'\frac{a}{b}$ read $\sqrt{1.2.A'\frac{a}{b}}$, and $3A'\frac{a}{b}$.

11. *Act. schlegeli.* For $3\,A'RDP\frac{ab}{\times}$ read $3\,A'DPP'P''\frac{ab}{\times}$.

12. *Act. typica.* For $1A'RD\frac{o}{o}$ read $1A'RD\left\{PP'-P_{VI}\right\}\frac{o}{o}$.

The presence of R or D in a formula indicates that the radial or distichal axillary "is a syzygy;" and this leads to confusion, for the two cases are not homologous. The radial axillary is *never* a syzygy in the sense that the distichal axillary is, or that the third or any following brachial may be; *i. e.* it never primitively consists of two

[1] *Loc. cit.* p. 258. [2] Gattung *Comatula*, p. 261.

joints which become immovably united and behave in all respects as one. But it may be united by syzygy to the second radial, instead of by the usual bifascial articulation[1]. This, however, is of an altogether different morphological value from the syzygial unions of the arm-joints. In the latter case the hypozygal entirely loses its individuality as a separate joint, and bears no pinnule as the epizygal and the remaining brachials do. Thus, for example, in very nearly all *Comatulæ* the original third and fourth joints of the growing arm differ from those which ultimately appear beyond them. For "whilst the majority of these gradually come to possess the true articulations, and to be separated by the intervention of muscles and ligaments, a certain small proportion become more intimately united on a simpler plan, which admits of no motion between them"[2]. The double or syzygial joints thus formed resemble the ordinary brachials in bearing but one pinnule, and they are therefore best considered as single joints. In *Ant. rosacea*, for example, the 3rd and 4th, the 9th and 10th, and the 14th and 15th joints of the growing arm are respectively united in pairs by syzygy; but the arm is best described as having syzygies in the 3rd, 8th, and 12th joints. So again in the numerous *Comatulæ*, such as *Act. parvicirra*, which have axillaries on some or all of the primary arms. Counting from the third radial, the distichal axillary is primitively the fourth joint. The first, as is almost invariably the case, bears no pinnule, while the second does bear a pinnule, but the third not; for it is united to the following (axillary) joint by a syzygy. The first ray-division would therefore be described as consisting of three distichal joints, the second bearing a pinnule, and the third (axillary) being a syzygy.

In *Encrinus*, in most recent species of *Pentacrinus*, in a few Comatulæ (*Act. solaris*, &c.) the two outer radials and the first two joints beyond them are respectively united by syzygy; and on the principle explained above, each pair would be considered as forming a single joint, so that the true third brachial (itself a syzygial joint) would come to be the second. This would involve our describing these forms as having but two radials, the axillary with a syzygy, and syzygies both in the first and in the second brachials. I think, however, that this would be misleading and make the difference between the two types appear much greater than it really is.

The presence of three radials is such an absolutely constant character in all the five-rayed Neocrinoids, excepting *Metacrinus* & *Plicatocrinus*, that the fact of the two outer ones being united by syzygy and not articulated seems to me to be of minor importance; and I do not assign to it the same morphological value as the syzygial union of the third and fourth primitive brachials, in which

[1] I use this name to denote the presence of a ligamentous bundle on either side of a vertical articular ridge, while muscles are absent. In by far the greater number of *Comatulæ* this is the mode of union of the two outer radials and of the first two joints beyond each axillary. It also occurs in *Millericrinus*, *Apiocrinus*, *Pentacrinus decorus*, *P. blakei* and other types. But in *Bathycrinus* there is a trifascial articulation, a small additional bundle of fibres being inserted into the apposed faces of the joints at the lower or dorsal end of the articular ridge.

[2] W. B. Carpenter, Phil. Trans. 1866, p. 721.

the former loses its pinnule. No Crinoid with three radials ever has a pinnule on the second one; and when this becomes the hypozygal of a syzygy, it does not therefore lose its individuality, as is the case with the hypozygals of the brachial syzygies. Almost the same may be said respecting the first two brachials. Most *Comatulæ* have a syzygy in the third brachial with a bifascial articulation between the two preceding joints, the second only of which bears a pinnule. Hence where these two are united by syzygy, as in *Act. solaris*, the first or hypozygal loses no individuality as an arm-joint. They are therefore better described as the first and second brachials, and not as a first brachial which "is a syzygy." This method has the advantage of retaining the third brachial as a syzygial joint as a condition which is common to by far the larger number of *Comatulæ*; for it is only a very few species, like *Act. fimbriata* and *Act. multiradiata*, which have a syzygy in the second brachial and a pinnule on the first. This is an entirely different type, and arises from the coalescence of the primitive second and third joints of the growing arm.

I cannot, therefore, regard as satisfactory Prof. Bell's formulæ for *Act. solaris*, *Act. brachiolata*, *e. g.* $1.2.A'R\frac{b}{a}$ and $1.2.A'R\frac{b}{b}$. For the radial axillary is not a syzygy in the same sense as the distichal axillary is in *Act. parvicirra*; neither is the first brachial a syzygy in the same sense as the second or, as I should call it, the third.

I am bound to say, however, that I am in some measure responsible in the matter of the first brachials, having employed this mode of description in my diagnoses of the Leyden *Comatulæ*[1]; but since then I have decided to abandon it, as will be seen from my descriptions of *Act. solaris* and *Act. robusta* of the Hamburg Museum, to to which I have added a few of my reasons for the change[2].

The erroneous character of some of the formulæ given by Prof. Bell is due, I fear, to his not having properly understood the descriptive terminology which I have been led to employ. I have endeavoured, as much as possible, to make it simply an extension of that used by Müller; and I have consequeutly used the word "rays" in the same sense as Müller did, as I have pointed out above[3]. Prof. Bell, however, seems not only to use it in a different sense himself, but also to have understood me as doing so. The result is that many of the formulæ which he has drawn up on the basis of my descriptions are utterly at variance with them.

The following is an abbreviated extract from the classification of the species of *Actinometra* in the Leyden Museum, together with the formulæ assigned to those species by Prof. Bell:—

A. Second and third radials united by syzygy.

a. Ten arms. ..... *solaris*. $1.2.A'R^{b}_{a}$.

β. Many arms. Rays may divide five times or more. First

[1] Notes from the Leyden Museum, vol. iii. pp. 170–217.

[2] "The Comatulæ of the Hamburg Museum," Journ. Linn. Soc. Zoology, vol. xvi. pp. 514–519.

[3] P. 732, note.

division of 3 joints, the axillary with a syzygy. Subsequent divisions of two joints united by syzygy.

novæ-guineæ. $1(2)A'RDP^{b}_{b}$.

typica. $1A'RD^{o}_{o}$.

B. Second and third radials united by ligament.

Many arms. First ray-division of three joints, the axillary with a syzygy.

α. Rays divide three times. Subsequent divisions like the first.

robustipinna. $A'(D)P^{c\,t}_{\times}$.

japonica. $\sqrt{3A'R^{o}_{b}}$.

parvicirra. $3A'DP^{(b)}_{a}$.

β. Rays may divide five times or more.

I. Third and fifth ray-divisions like the first. Second and fourth divisions of two joints, the axillary without a syzygy.

alternans. $3A'RPP''^{o}_{o}$.

II. All ray-divisions like the first.

schlegeli. $3A'RDP^{ab}_{\times}$.

bennetti. $3A'RDP^{c}_{b}$.

peroni. $3A'RDP^{b}_{b}$.

Prof. Bell's formulæ do not give any thing like a proper idea of the characters of *Act. novæ-guineæ* and *Act. typica*, especially the latter. Both species are among "those rare cases in which divisions extend beyond the palmars;" and Prof. Bell should therefore have made use of his symbols P′ and P″. These two would have sufficed for *A. novæ-guineæ*, which has only two axillaries beyond the palmars. Strictly speaking, however, neither P, P′, nor P″ have any proper place in the formula; for the palmar and subsequent axillaries are not syzygial joints homologous with the distichal axillaries, any more than the radial axillary is, either in these two species or in the *solaris* group; and as pointed out above, it is equally incorrect, for morphological reasons, to describe the first brachials as being syzygial joints homologous with the third brachials

[1] It is absurd to put the D within brackets in this formula, because the only specimen described has no syzygy in the axillaries of three out of the nine primary arms. I have described a specimen of *Act. parvicirra* in which five out of the ten distichal axillaries have no syzygy, and another in which there are four axillaries with and four without a syzygy. Here therefore we have a character which "frequently though not always obtains" just as in *Act. robustipinna*. Why is the one case noted in the formula but not the other? Prof. Bell's experience of the variations in these characters must surely have taught him that it is the exception and not the rule for all the distichal and palmar series of any many-armed specimen to be exactly alike, and that a specific diagnosis must be based on the characters of the majority. When, however, some specimens of any type have distichals or palmars, and others may be altogether without them it is useful to put the D or P within brackets; and this should have been done in Bell's formula for *Act. parvicirra*, as I shall shortly point out.

of *Ant. rosacea* and *Ant. eschrichti*, or with the second brachials of *Act. fimbriata* and *Act. multiradiata*.

In the case of *Act. typica*, the employment of a shorthand has been carried to such an extent by Prof. Bell, that he only makes provision for 20 out of the 80 or more arms that the species possesses. The P which is inserted into the formula for *Act. novæ-guineæ* is here omitted, and only two of the axillaries taken into consideration at all. Nevertheless the rays have been described by myself as dividing seven or eight times; *i. e.* there may be no less than five axillaries beyond the palmars, all united by syzygy to the preceding joints as the palmar axillaries are; while Lovén[1] has figured a specimen with two axillaries beyond the palmars and has described the species as having 80 arms. Prof. Bell's formula, however, ($1A'RD^{0}_{0}$) takes no account of any palmars at all, much less of any thing beyond them, although Lovén says "*Rami secundi quatuor, bina paria, e brachialibus duobus*," and goes on to speak of *rami tertii, quarti*, and *quinti*; but the presence of the D and nothing more in Prof. Bell's formula indicates that the total number of arms is never more than 20 and may be only 11!

It will be evident from the classification detailed above, that the essential character common to all the seven species of group B is the union of the second and third radials by ligaments and not by a syzygy as in the three species of group A. Nevertheless five of the seven formulæ given by Prof. Bell contain an R, which denotes that the radial axillary "is a syzygy." He surely cannot imagine that the radial axillaries which are united by ligament to the second radials are themselves syzygial joints as the distichal axillaries are. I have described the form of the axillaries in each of these five species, but have not said one word about their being syzygial joints. Such a condition, *i. e.* syzygial axillaries united by ligaments to the second radials, occurs in no *Comatula* with which I am acquainted.

Neither are the axillaries united to the second radials by syzygy, as in *Act. solaris* and the other species of Group A, the formulæ for all of which contain an R. It is therefore difficult to understand why the formulæ for five of the species of group B should contain an R which is absent from those of the two remaining species. I can think of no reason for this except that in the diagnoses of these five species I have spoken of the "first ray-division" as consisting of three joints, the axillary with a syzygy. Prof. Bell, who appears to consider the primary number of rays as 10, and not five, as described by Müller and myself, has perhaps understood the term "first ray-division" to mean the five undivided rays themselves, which consist of the first, second, and third (axillary) radials. I had hoped that this expression coming immediately after the statement "the rays (in the Müllerian sense) dividing" 2, 3, or more times, and preceded by the description of the radial axillary where the division occurs, would be interpreted as meaning the ten primary arms which are borne by the axillaries and are themselves con-

[1] Öfv. af. K. Vet.-Akad. Förh. 1866, p. 230.

veniently described as consisting of distichal joints. But in order to avoid misconception, I expressly inserted the word distichals in speaking of the first division of the rays of *Act. pulchella*[1]. The description of this species was written before those of the Leyden *Comatulæ*, and must have been read by Prof. Bell, as he gives a formula based upon it.

I cannot help suspecting, however, from the formula which he gives for *Act. alternans*, that he has thus misunderstood my meaning. It is as follows, $3A'RPP''\frac{0}{0}$. This can only be interpreted in the following way:—that the radial axillary "is a syzygy" (which is not the case); that there are two distichals[2], the axillary without a syzygy (while there are really three, the axillary with a syzygy); that there are two or three palmars, the axillary with a syzygy (while there are really two, the axillary without a syzygy); and so on for the two remaining divisions, so that the formula should read $3A'DP'P'''\frac{0}{0}$. Even then, however, it would not indicate whether two or three distichals are present[3], nor whether there are one or two palmars, nor the number of joints in the two remaining divisions; so that one would be entirely at a loss as to the systematic position of the type.

Prof. Bell gives the formula for *Act. japonica* as $\sqrt{3A'R}\,\frac{c}{b}$. Even after the removal of the unnecessary and totally misleading R, the formula is entirely incorrect as regards the ray-divisions, and says nothing about any palmars being present. It means that there are two distichals, the axillary not a syzygy. But in Müller's classification this species is placed in a group distinguished as follows, "Die Axillaria der Arme mit Syzygien;" and my own description runs, "Primary and secondary arms each of three joints, the axillary a syzygy," or, as Prof. Bell puts it, "Three distichals and three palmars, the axillaries syzygies." His formula should therefore be $3A'DP\,\frac{c}{b}$.

The formula which he gives for *Act. parvicirra* $\left(3A'DP\,\frac{(b)}{a}\right)$ implies that palmars are always present on some of the rays. A specimen has been figured, however, with 13 arms only, having distichals on only three rays and no palmars at all; and others have been noticed with but 18 and 20 arms[4]. The P should therefore be put within brackets, and the formula stand $3A'D(P)\,\frac{(b)}{a}$, like that of *Act. wahlbergi*, Müll., and *Act. variabilis*, Bell, MS.

In like manner the formula given for *Act. peroni* $\left(3A'RDP\,\frac{b}{b}\right)$ does not convey the information that there may be another axillary

[1] Bull. Mus. Comp. Zool. vol. ix. no. 4, p. 10.

[2] I am at a loss to understand how Prof. Bell can have supposed that the second joint after the radial axillary, which is described as bearing a pinnule, can at the same time be an axillary joint; but no other types without a syzygy in the axillary than a series of two distichals have yet been described.

[3] *I. c.* unless the rule be known that if the distichal axillary is a syzygy it is always the third joint, and not the second, as may sometimes be the case with the palmars.

[4] Trans. Linn. Soc. 2nd series, Zool. vol. ii. 1879, p. 44, and pl. ii. fig. 9.

beyond the palmars. It should read $3\,A'DP(P')\,\frac{b}{b}$. There may be yet another in *Act. bennetti* and the number of arms reach 70 or 80, which is only very rarely the case among the *Comatulæ*. Prof. Bell's formula $(3\,A'RDP\,\frac{c}{b})$, however, only provides for 40, which is a very common condition. The formula should therefore be $3\,A'DPP'(P'')\,\frac{c}{b}$. The same may be said of *Act. schlegeli*, the only known example of which has two axillaries beyond the palmars and over 80 arms. Its proper formula would be $3\,A'DPP'P''\,\frac{ab}{x}$, while Prof. Bell gives $3\,A'RDP\,\frac{ab}{x}$, which provides for less than half this number of arms, so that one of the most evident specific characters is not taken into account at all.

The ray-divisions of *Act. pulchella* have been thus described:—"10–20 arms, most of the rays usually dividing twice, the first division (distichals) consisting of two joints which are not united by syzygy. When the arms spring directly from the radial axillary, the two lowest brachials are united by ligament, as in most *Comatulæ*, and the third is a syzygial or double joint. But in all the arms which spring from a distichal axillary the two lowest brachials are united by syzygy to form a double joint; and the true third brachial, which is also a syzygial joint, as in all *Comatulæ*, thus becomes the second arm-joint, as in *Act. solaris*"[1]. Two formulæ are necessary for this type—one for the ten-armed form, and another for that with divided primary arms. The first would be $3\,A'^{a}_{b}$, and the second $\sqrt{1.2\,A'^{a}_{b}}$. Prof. Bell, however, writes $(1.2)3\,A'^{a}_{b}$, thus taking no account of the presence of distichal axillaries in some (often all) of the primary arms; and his formula also implies that the first, second, and third brachials of the same arm may all be syzygial joints, which is never the case.

One very serious objection to Prof. Bell's system of shorthand is that (except in one case) it is only applicable to those *Comatulæ* in which the ray-divisions are regular, *i. e.* with the second and subsequent divisions all resembling the first. For regular forms like *Act. parvicirra*, *Act. bennetti*, and their allies, which have three distichals and three palmars with a syzygy in each axillary, Prof. Bell's notation is probably as short a one as could be devised; though it gives no information respecting the number of joints in each series, and does not always indicate whether palmars are present or not. Thus, for example, his formula for *Ant. articulata* is $\sqrt{3\,A^{c}_{b}}$. This means that distichals are present but do not "present a sygygial joint." It does not indicate, however, whether the axillary is the fourth joint (an actual case in another species), the first (which I have never met with), or the third, or the second (as is really the case). But no information is given at all respecting the presence or

[1] Bull. Mus. Comp. Zool. vol. ix. no. 4, p. 10. October 1881. Were I writing now, I should insert the word "nearly" before "all *Comatulæ*" in the last sentence.

absence of palmars or of any further ray-divisions. One finds the same deficiency of information in the formulæ for the following species, viz. *Antedon bimaculata, brevicuneata, elongata, flagellata, lævicirra, macronema, palmata, reginæ, spinifera.* Had I not examined eight of these personally, I should be unable to classify them properly from Prof. Bell's formulæ alone. The remaining one (*Ant. reginæ*) is an MS. species of his; and I am therefore unable to give it a place in the classified list of species which concludes this paper.

The only irregular types to which Prof. Bell's notation is at all applicable are those like *Act. rotalaria*, which have two distichals and three palmars, with a syzygy in the last axillary but not in the distichal one. He gives the formula of this species as $3\,A'(P)\frac{a}{\times}$; but this tells us nothing as to the number of the distichal joints; and Prof. Bell is unable to carry out his plan of inserting the sign $\surd$ to indicate that the distichal axillary is not a syzygy, because it would not apply to the palmars. A specialist would know that there are only two forms of distichal series yet described in *Actinometra*, viz. two joints, the axillary without, and three joints, the axillary with a syzygy; so that the omission of D from Prof. Bell's formula would lead him to infer that only two distichal joints were present in the corresponding species. But Prof. Bell gives no hint of this fact for the benefit of the uninstructed collector; and should an *Actinometra* ever be discovered with four distichals and three palmars (the last axillary a syzygy), instead of two palmars without a syzygy (as is actually the case in one species), it would have the same formula as *Act. rotalaria*, though widely different from it in reality[1].

When, however, the case of *Act. rotalaria* is reversed, and there are three distichals and two palmars, the distichal axillary having a syzygy and the palmar not, Prof. Bell's notation is altogether insufficient. He cannot insert a P, because there is no syzygy in the palmar axillary; and he cannot use the sign $\surd$, because there is a syzygy in the distichal axillary. He is therefore obliged to content himself with making no mention of any palmars at all. Omitting the cirrus-characters, we find his formulæ for the six following species to be all of the same general type, viz. 3 A (or A') D. The species are—*Antedon briareus, A. decipiens, A. irregularis,* and *A. savignii*, *Actinometra trichoptera* and *A. multifida*. All of them have three distichals with the axillary a syzygy; but some of them, *Ant. savignii* and *Act. multifida*, also have two palmars, while others, like *Act. trichoptera*, have not. Prof. Bell, however, gives the same group-formula in each case, so that I am unable to refer his two species, *Ant. decipiens* and *Ant. briareus*, to their proper positions; and I have only been able to place *Ant. irregularis* in my classified list, owing to his having kindly permitted me to examine it for myself. Both *Ant. decipiens* $\left(3\mathrm{AD}^{\mathrm{p}}_{\mathrm{p}}\right)$ and *Ant.*

[1] I am here speaking only of the ray-divisions, and take no account of the characters of the cirri, which might or might not be different in the two species.

briareus $\left(3\,\mathrm{AD}^{b}_{a}\right)$ have the same formula, except as regards the number of joints in the cirri; but, for all I know, the one may have 20 arms only and the other 40, 60, or more. *Act. multifida* is a many-armed form of this kind, having two joints in the palmar and subsequent ray-divisions. Müller describes the number of arms as 40–44, and I have seen individuals with even more; but Prof. Bell gives the species-formula as $3\,\mathrm{A'D}^{b}_{a}$, *exactly* the same as that of *Act. trichoptera*, which has no palmars and 20 arms or less!

I cannot imagine what has led Prof. Bell to suppose that the radial axillary of *Act. multiradiata* "is a syzygy," so that he has inserted an R into his formula. Müller made no mention of it in his description of the type, as he did in the case of *Act. solaris* and its allies; and in a memoir[1] now three years old, after personally examining the type specimens at Paris, I placed the species in a group distinguished as follows—"Second and third radials united by ligament only." Surely Prof. Bell has not understood Müller's expression, "Die axillaria der *Arme* mit Syzygien," to include the *radial* axillary also[2]. With this R omitted and a missing (P') inserted, the formula becomes $2\,\mathrm{A'DP(P')}^{b}_{b}$; but it gives no information whatever respecting the number of joints in the distichal and palmar series. When the distichal axillary "is a syzygy," it is either united by syzygy to the preceding joint (*Act. jukesi*), or there are two joints below it, so that it is really the third distichal. This rule is an invariable one; but even supposing it to be known to the readers of Prof. Bell's formulæ, the same does not hold good with the palmars. For the palmar axillary, which "is a syzygy," may be the third of its series, as in *Act. parvicirra* and *Act. bennetti*, or the second, as in *Act. multiradiata*; or, like the distichal axillary of *Act. jukesi*, it is syzygially united to the preceding joint, as in *Act. typica*. Prof. Bell's formula, however, gives no information about this, and the special distinctive character of the *multiradiata* group is thus altogether lost sight of, unless No. 5 of the following Rules be understood as known; but Prof. Bell is silent upon this point.

The weakness of his method of formulation is partly due to the following cause:—The same symbol (D or P) is used indifferently, whether there are three or two joints, the axillary with a syzygy, or two joints united by syzygy. I should say, however, that the figure indicating the position of the first brachial syzygy would in most cases explain to an experienced worker which type was meant, as is shown in the general rules stated below; but Prof. Bell gives no hint of this.

The formula 3DP, which he gives for *Act. parvicirra*, would thus admit of any of the nine following explanations, the third brachial being a syzygy in all cases, and the two outer radials united by ligament. In the other two columns are recorded some existing species, the distichal and palmar axillaries of which are syzygies,

[1] Trans. Linn. Soc. 2nd ser., Zool. vol. ii. p. 27.

[2] The italics are mine.

while the first arm-syzygy is not on the third, but on the second brachial, or between the first and second.

Group.	*Actinometra.*	3rd br. Sy.	2nd br. Sy.	1—2 br. Sy.
I.	3 distichals and 3 palmars, the axillaries syzygies	*parvicirra.*		
	3 distichals and 2 palmars, the axillaries syzygies	.....	*multiradiata.*	A.
	3 distichals, the axillary a syzygy; and 2 palmars united by syzygy.....	.....	.....	B.
II.	2 distichals, the axillary a syzygy; and 2 palmars united by syzygy.			
	2 distichals and 2 palmars, the axillaries syzygies.			
	2 distichals and 3 palmars, the axillaries syzygies.			
III.	2 distichals united by syzygy; 2 palmars united by syzygy.			
	2 distichals united by syzygy; 2 palmars, the axillary a syzygy.			
	2 distichals united by syzygy; 3 palmars, the axillary a syzygy.			

Now, unless Rule 3 were known, how should any one, taking the corrected formula for *Act. parvicirra* $\left(3A'D(P)^{(b)}_{a}\right)$, or for *Act. multiradiata* $\left(2A'DP(P')^{b}_{b}\right)$, know that he could only have to deal with types belonging to one of the first two groups? And unless he were also acquainted with Rule 7, he could not know that Group II. represents a series of types that are as yet undiscovered. But within Group I. the chances of error would be two to one unless Rule 5 were known, according to which the third (or second) brachial is only a syzygy when there are three (or two) palmars, the axillary with a syzygy. There may, however, be two palmars with the axillary a syzygy, and yet the first two brachials be united by syzygy, as in species A of the scheme above. This exception, to which others will doubtless soon be added, also shows the weakness of Prof. Bell's system, even supposing the following rules to be understood; for its formula would be 1DP, identical with that of another more regular species, B of the above scheme, to say nothing of half a dozen other possibilities in Groups II. and III.

A working method of formulation, therefore, must be elastic enough to deal with such anomalies as A, and indicate exactly on what joint the syzygy comes in the distichals, palmars, and brachials. Further, when there are no syzygies in the ray-divisions, whether throughout them all (*Ant. palmata*) or in some only (*Act. alternans*), the number of joints in each division should be clearly indicated. Thus the formula 3 A'D, as understood by Prof. Bell, would stand for any one of the following existing types of *Actinometra*, apart from any number of possibilities.

Act. trichoptera...	No palmars.	All with a syzygy in the distichal, but not in any other axillary.
α.	1 palmar (axillary).	
β.	1 palmar, and 1 axillary beyond it.	
γ.	2 palmars.	
Act. multifida ...	2 palmars, and another similar division.	

The want of elasticity which renders Prof. Bell's system so misleading will not be found, I hope, in that which I am now about to explain. It has grown up gradually during seven years' work, and will meet all the variations of actual *Comatula*-structure with which I am acquainted, together with any others that I can imagine as possible. Some time ago I pointed out that "the first and second segments beyond every axillary, whether radial or brachial, are nearly always united together in the same manner as the second and third (axillary) radials." Further experience has shown that the "nearly" embraces several well-marked but regular exceptions to the above statement; and I have therefore drawn up the following rules, which embody the results of my study of the group. They are not to be in any way regarded as *laws* of *Comatula*-structure, but merely as generalizations based upon a knowledge of some 400 species, and therefore, I hope, of some value for the purpose of classification.

1. All ten-armed species of *Actinometra* which have the two outer radials united by syzygy, have the first two brachials united in the same way.

Ex. *Act. solaris.* No *Antedon* known.

2. All many-armed species of *Actinometra* which have the outer radials united by syzygy either have (α) all the ray-divisions of two joints also united by syzygy and the first two brachials similarly united; or (β) there may be three distichals, of which the first two are articulated and the axillary is a syzygy, while the subsequent divisions are as above.

Ex. α. *Act. jukesi*; β. *Act. typica.*

3. If the two outer radials are united by a ligamentous articution, the next two joints are similarly united, whether there be ten or many arms. In the former case the third brachial is almost always a syzygy. (One of the "Blake" *Comatulæ* is an exception.)

Ex. *Ant. rosacea, Ant. philiberti, Act. meridionalis, Act. parvicirra.*

4. In by far the greater number of *Comatulæ* which have the two outer radials articulated by ligaments and only two ray-divisions, the third brachial is the lowest syzygial joint on the arms, whether the distichal axillary be a syzygy or not; and the two lowest brachials are articulated by ligaments.

Ex. *Ant. macronema, Ant. reynaudi, Act. trichoptera.*

Exceptions. *Act. fimbriata* and *Act. borneensis*, with some undescribed *Antedon*-species, have the second brachial a syzygy, like the distichal axillary. *Act. pulchella* and a new 'Challenger' *Antedon* have two distichals the axillary not a syzygy, but the first two brachials united by syzygy.

5. If the two outer radials are articulated and there are more than two ray-divisions, so that palmars are present, the third brachial is the first arm-syzygy in all cases but the following:—

a. Two palmars united by syzygy; the first two joints beyond the palmar and all subsequent axillaries are also united by syzygy.

Ex. Species B. of above scheme.

β. Two palmars, the axillary a syzygy; the second joints beyond the palmar and all subsequent axillaries also have a syzygy.

Ex. *Act. multiradiata.*

Species A of the above scheme, with the first two brachials united by syzygy, is an exception.

6. Whenever any ray-division, distichal, palmar, or any other, consists of three joints, the first two are articulated by ligaments, the second bearing a pinnule, and the third (axillary) is a syzygy just as in the first three brachials of *Ant. rosacea* and *Act. echinoptera*. When, however, there are only two joints, and the second (axillary) is a syzygy, the first has a pinnule, just as in the arm-bases of *Act. fimbriata.*

7. The hypozygal of a syzygy is always united to the preceding joint by a muscular articulation.

Like Prof. Bell, I should use R to denote the syzygial union of the two outer radials. When ten arms only are present, this is indicated by 10 in the formula. This may be thought unnecessary, as the absence of any signs for the distichals would indicate that the primary arms remained undivided; but I find that it is more convenient to indicate this character, which is generally a sharply defined one, in a positive rather than in a negative manner. I also assume, in accordance with Rules 3–5, that the first syzygy on the arm is on the third brachial, unless otherwise stated. If it is on the second brachial, I put 2 b at the end of the formula; and if the first two brachials are united by syzygy, $\frac{b}{2}$ is used. In like manner, and in accordance with Rule 5, 2 d and 2 p would indicate that there are two distichals or two palmars, of which the axillary is a syzygy; and $\frac{d}{2}$ or $\frac{p}{2}$ that the two distichal or palmar joints are united by syzygy.

The figures 1 or 2 alone would indicate that there is either only a single axillary joint, or two which are united by ligament; and a 3 would denote three joints, of which the axillary is a syzygy[1]. If one figure occurs alone in a formula, it indicates the presence of distichals only; two figures, that palmars occur as well; and so on, an additional figure being added for each ray-division, e. g. *Act. alternans* 3,2,3,2.

This may be tabulated as follows:—

Character.	Symbol used. Distichal.	Palmar.
One axillary joint	1	1.
Two joints united by syzygy	$\frac{d}{2}$	$\frac{p}{2}$.
Two articulated joints	2	2.

[1] It would, of course, be more consistent to write 3 d, or 3 p; but the syzygial nature of the third (axillary) joint is such a constant character (Rule 6) that, until an exception is met with, I prefer to use the figure alone, for the sake of brevity.

Character.	Symbol used. Distichal.	Palmar.
Two joints, the axillary a syzygy ..	2 d[1]	2 p.
Three joints, the axillary a syzygy..	3	3.
Four joints, the axillary not a syzygy	4	4.[1]

As in Prof. Bell's system, the insertion of any sign within brackets ( ) would indicate the variable occurrence of the corresponding character.

I subjoin the formulæ for some typical examples of the proposed system, all of which, with the exception of *Act. jukesi*, are to be found described at length elsewhere.

Antedon.

rosacea ..... A. 10.
macronema ..... A. 2.
palmata ..... A. 2.2.(2).
rubiginosa ..... A. 3.
savignii ..... A. 3.2.
philiberti ..... A. 3.3.

Actinometra.

$\alpha\beta$ *solaris* ..... a. R. 10. $\frac{b}{2}$.
$\alpha\beta$ *jukesi* ..... a. R. $\frac{d.b.}{2}$
β *novæ-guineæ* ..... a. R. 3. $\frac{p.p'.p''.b.}{2}$.
meridionalis ..... a. 10.
pulchella ..... a. 10. and a. 2. $\frac{b}{2}$.
γ *rotalaria* ..... a. 2.3.
trichoptera ..... a. 3.
fimbriata ..... a. 3.2 b.
δ *multiradiata* ..... a. 3.2 {p.(p')b}.
alternans ..... a. 3.2.3.2.
parvicirra ..... a. 3.(3).
schlegeli ..... a. 3.3.3.3.

α. The $\frac{b}{2}$ might be omitted in accordance with Rules 1 and 2; but its presence more readily indicates the relationship of these two species to *Act. novæ-guineæ*, &c.

β. Another figure might be usefully added in order to indicate whether the next syzygy is in the third or in some subsequent brachial.

γ. As determined by myself. Müller's description is incorrect.

δ. The brackets { } are used in order to avoid repeating the 2 before each letter. The b. might be omitted in accordance with Rule 5, but is retained to indicate the relationship of this species to *Act. fimbriata*.

[1] Hitherto unobserved.

I subjoin the formulæ for all the variations of structure that I have met with among the *Comatulæ*, together with the names of nearly all the described species to which the respective formulæ apply. Grube's two species, *C. lævissima* and *C. mertensi*, are referred by Prof. Bell to *Antedon*, and probably correctly so; but two other species in his *Antedon*-list have no existence, viz. *alata* and *meridionalis*. The former is identical with the *Antedon pulchella* of Pourtalès and was referred to *Actinometra* in 1881, while the latter also belongs to this genus[1]. Some of Prof. Bell's MS. species are also omitted, owing to the incompleteness of the formulæ which he gives for them.

Lists of Formulæ.

Antedon.

I.	A. R.3.	
	A. R.3.2.2.	
	A. R.3.3.	
II.	A. 10.[2]	*adeonæ, antarctica, armata, brevipinna, carinata, celtica, cubensis, dentata*[3], *dubeni, eschrichti, hageni, insignis, jacquinoti, lovéni, milberti, milleri, lævipinna, perspinosa, petasus, phalangium, pinniformis, prolixa, rosacea, rubiginosa, serripinna.*
III.	A. 2. $\frac{b}{2}$.	
	A. 2.	*brevipinna, macronema.*
	A. 2.2.	*æquipinna, articulata, bimaculata, brevicuneata, elongata, flagellata, imparipinna, indica, lævicirra, palmata, protecta, spicata, spinifera.*
	A. 2.2.2.	*palmata.*
IV.	A. 3 $\frac{b}{2}$.	
	A. 3.	*briareus, decipiens, elegans, reynaudi*[4], *rubiginosa.*
	A. 3.1.	
	A. 3. $\frac{p.b}{2}$.	
	A. 3.2.	*acuticirra, crenulata, granulifera, irregularis, ludovici, savignii, variipinna.*
	A. 3.2.3.	

[1] See Bull. Mus. Comp. Zool. vol. ix. no. 4, 1881, pp. 6, 9.

[2] In cases like this, when there are a large number of species in any given group, some further mode of classification becomes necessary; and the notation proposed by Prof. Bell for the varying characters of the cirri is very useful for this purpose.

[3] This species is undoubtedly identical with the *Ant. sarsii* of Düben and Koren; and as Say's name is the older by nearly twenty years, I feel that it is only right to follow Prof. Verrill in restoring it.

[4] The formula given by Prof. Bell for this species is based on Müller's description, which is incorrect. It should be 3 AD $\frac{b}{c}$.

	A. 3.2{p.b.}.	
	A. 3.3.	*bipartipinna, elegans, microdiscus, philiberti.*
	A. 3.3.3.	
V.	A. 4.	

Actinometra.

I.	a. R. $10\frac{b}{2}$.	*affinis, albonotata, pectinata, purpurea, robusta, rosea, solaris.*
II.	a. R. $\frac{d.b}{2}$.	*julcesi, paucicirra?*
	a. R. $3\frac{p.p'.p''.b}{2}$.	*novæ-guineæ, typica.*
III.	a. 10. 2b.	
	a. 10.	*coppingeri, cumingi, echinoptera, meridionalis, pulchella.*
IV.	a. $\frac{d.p.p'b}{2}$.	
	a. 2. $\frac{b}{2}$.	*pulchella.*
	a. 2.	
	a. 2.2.	*stelligera.*
	a. 2.2.2.	
	a. 2.2.2.2.	
	a. 2.3.	*rotalaria.*
	a. 2.3.3.	
	a. 2.3.3.3.	
V.	a. 3. $\frac{b}{2}$.	
	a. 3. 2b.	*borneensis?, coccodistoma, fimbriata.*
	a. 3.	*parvicirra, trichoptera, variabilis, wahlbergi.*
	a. 3.1.	
	a. 3.1.1.	
	a. 3. $\frac{p.b.}{2}$.	*B.*
	a. 3.2.	
	a. 3.2.2.	*multifida.*
	a. 3.2.3.	*grandicalyx.*
	a. 3.2.3.2.	*alternans.*
	a. 3. $\frac{2}{3}\left(\frac{o}{i}\right)^1$ 2.2.	
	a. 3. $\frac{2}{3}\left(\frac{o}{i}\right)^1$ 3.3.	
	a. 3. 2p. $\frac{b}{2}$	*A.*
	a. 3.2{p.b}.	*lineata.*
	a. 3.2{p.p'.b}.	*multiradiata.*
	a. 3.3.	*annulata, japonica, meyeri, parvicirra, robustipinna, variabilis, wahlbergi.*
	a. 3.3.2.	
	a. 3.3.3.	*bennetti, peroni.*
	a. 3.3.3.3.	*bennetti, schlegeli.*
VI.	a. 4.2.2.2.2·2.	

[1] *I. e.* the two outer palmar series on each ray are formed of two joints only, the axillary without a syzygy; while the two inner series consist of three joints, the axillary with a syzygy.